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Tobacco outlet density and tobacco knowledge, beliefs, purchasing practices and price among adolescents in Scotland

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Abstract

Despite long-term falls in global adult smoking prevalence and over 50 years of tobacco control policies, adolescent smoking persists. Research suggests greater densities of tobacco retail outlets in residential neighbourhoods are associated with higher adolescent smoking rates. Policies to reduce retail outlets have therefore been identified by public health researchers as a potential 'new frontier' in tobacco control. Better understanding of the pathways linking density of tobacco retailers and smoking behaviour could support these policies.

In this study we use path analysis to assess how outlet density in the home environment is related to adolescent tobacco knowledge, beliefs, retail purchases and price in Scotland. We assessed 22,049 13 and 15 year old respondents to the nationally representative cross-sectional 2010 Scottish School Adolescent Lifestyle and Substance Use Survey. Outlet density was based on Scottish Tobacco Retailers Register, 2012, data. A spatially-weighted Kernel Density Estimation measure of outlet density within 400m of respondents' home postcode was grouped into tertiles. The analysis considered whether outlet density was associated with the number of cigarette brands adolescents could name, positive beliefs about smoking, whether smokers purchased cigarettes from shops themselves or through adult proxies and perceived cost of cigarettes. Models were stratified by adolescent smoking status.

The path analyses indicated that outlet density was not associated with most outcomes, but small, significant direct effects on knowledge of cigarette brands among those who had never smoked were observed. With each increase in outlet density tertile the mean number of brands adolescents could

name rose by 0.07 (mean=1.60; SD=1.18; range=4). This suggests greater outlet densities may have affected adolescents' knowledge of cigarette brands but did not encourage positive attitudes to smoking, purchases from shops or lower cigarette prices. Exposure to tobacco outlets may influence adolescents' awareness of tobacco products, a potential pathway to smoking behaviour.

Keywords

- smoking
- tobacco
- adolescents
- Scotland
- retail environment
- outlet density
- social norms
- neighbourhood

Introduction

Globally the prevalence of adult daily smoking has fallen in recent decades, however new adolescent smokers are still initiating smoking and it remains one of the leading risk factors for global disease burden (Ng et al., 2014). Therefore, international public health debate continues to focus upon the need to better regulate tobacco. Research in high-income countries has indicated greater densities of tobacco retail outlets in residential neighbourhoods are associated with greater prevalence of smoking among adolescents and adults (Gwon et al., 2016, Barnett et al., 2017). Public health researchers have suggested tobacco retail outlet density is a potential 'new frontier' for tobacco control (Cohen and Anglin, 2009, Gartner and McNeill, 2010). Recent research has estimated impacts of outlet reduction interventions (Pearson et al., 2014, Pearson et al., 2016) and initiatives to reduce outlets have been introduced in several countries (Ackerman et al., 2016). There is however limited quantified evidence of the mechanisms linking density of outlets to smoking behaviour to support this work.

This study assesses pathways which may link tobacco outlet density in residential neighbourhoods to smoking behaviours among adolescents in Scotland. Adolescents are at a key life stage when smoking is initiated and established and have distinctive interactions with outlets shaped by restrictions on tobacco sales. The paper first describes the relationship between tobacco outlet density and adolescent smoking behaviour, outlining a conceptual model of the causal pathways between them. The study then uses path analysis, a novel approach in this field which allows complex direct and indirect pathways to be modelled, to assess a selection of these hypothesised pathways.

Pathways linking tobacco outlet density and adolescent smoking behaviour

Analysis of tobacco outlet density in residential areas has commonly found a moderate positive association with adolescent smoking behaviours (Barnett et al., 2017), although this has been absent in some studies (Pokorny et al., 2003, Adachi-Mejia et al., 2012, Loomis et al., 2012). This research has mostly been completed in the USA (Pokorny et al., 2003, Adachi-Mejia et al., 2012, Cantrell et al., 2016, West et al., 2010, Lipperman-Kreda et al., 2012, Novak et al., 2006, Lipperman-Kreda et al., 2014b, Schleicher et al., 2016, Loomis et al., 2012) and has frequently measured outlet density in small neighbourhoods or home radiuses of a mile or less (Lipperman-Kreda et al., 2014b, Cantrell et al., 2016, Novak et al., 2006, Adachi-Mejia et al., 2012, Schleicher et al., 2016) but also across towns or cities (Pokorny et al., 2003, Lipperman-Kreda et al., 2012) and considered proximity to nearest outlet (West et al., 2010, Lipperman-Kreda et al., 2014b, Adachi-Mejia et al., 2012). It has identified an association between outlets and both adolescent smoking initiation (Cantrell et al., 2016, West et al., 2010, Lipperman-Kreda et al., 2012, Shortt et al., 2014, Schleicher et al., 2016) and current smoking (Novak et al., 2006, Shortt et al., 2014, Lipperman-Kreda et al., 2012, Lipperman-Kreda et al., 2014b).

Research which has considered outlet density in school areas has also found a relationship with adolescent smoking (Barnett et al., 2017, Gwon et al., 2016). However, three studies comparing outlet density near adolescents' home and school found an association with smoking for home area only (Shortt et al., 2014, Lipperman-Kreda et al., 2014b, Schleicher et al., 2016), suggesting home environment may matter more. In Scotland research found approximately 50% higher odds of having ever smoked and current smoking among 13 and 15 year olds living in the quartile of neighbourhoods with the highest outlet density relative to areas with no outlets (Shortt et al., 2014), but did not find greater likelihood of smoking in high density areas near schools.

Recent work by health geographers has theorised the mechanisms linking places and smoking behaviour (Pearce et al., 2012, Barnett et al., 2017). Figure 1 contains our conceptual model, drawing

on this work, to suggest how tobacco outlet density in the home environment could influence adolescent smoking behaviour. The conceptual model contains two sets of causal pathways, the first focussed upon the effects of outlet density upon residents and the second upon retailers.

The conceptual model hypothesises that in areas with greater tobacco outlet concentrations adolescents have more exposure to outlets and the products and promotion within them. This may influence adolescents' knowledge of tobacco and their beliefs about smoking. These pathways are supported by research demonstrating that adolescents living in areas with high outlet density report greater exposure to tobacco advertising (Loomis et al., 2012) and those that visited shops more frequently had greater knowledge of cigarette brands (Van Der Sluijs et al., 2016, Dauphinee et al., 2013). Adolescent's frequency of visits to tobacco outlets is associated with smoking initiation (Johns et al., 2013), exposure to tobacco point-of-sale promotion with experimentations with smoking, occasional smoking and regular smoking (Paynter and Edwards, 2009) and familiarity with cigarette brands with intention to smoke and smoking initiation (Grant et al., 2008, Spanopoulos et al., 2013).

Research suggests youths in high outlet density areas are more likely to believe that smoking makes you 'cool' or 'fit in' (Loomis et al., 2012). Familiarity with cigarette brands is associated with adolescent's beliefs that smoking is 'attractive' and cigarettes are 'worth spending money on' (Grant et al., 2008). Prominent tobacco retail may 'normalise' smoking, indicating that sale and use of tobacco products are common, socially accepted behaviours. Adolescents living in areas with greater outlet density have higher estimates of adult smoking rates (Schleicher et al., 2016). Their exposure to point-of-sale promotion is related to beliefs that tobacco is easy to buy from shops and estimates of prevalence of adult and teenage smoking (Henriksen et al., 2002, Wakefield et al., 2006). Beliefs about smoking prevalence have in turn been found to be associated with the likelihood of child and adult smoking (Conrad et al., 1992, Ahern et al., 2009). Outlets could contribute to local smoking

cultures and 'place-based practices' (Pearce et al., 2012) that underlie community patterns of smoking behaviour (Barnett et al., 2017).

The conceptual model also hypothesises that outlet density influences the likelihood smokers buy tobacco in shops. In Scotland the proportion of adolescents buying cigarettes from shops has declined substantially in recent years but a minority still reported purchases in 2013 (ISD Scotland, 2014). Studies in USA have found youths in outlet dense areas were more likely to attempt to purchase (Marsh et al., 2016) and buy their own tobacco (Leatherdale and Strath, 2007, Loomis et al., 2012). Tobacco outlets may act as environmental cues triggering tobacco purchases and smoking. Proximity to outlets is associated with urge to smoke among adult smokers (Watkins et al., 2013) and outlet density with reduced intention to quit among adolescents (Mennis et al., 2016). The sight of tobacco shops (Burton et al., 2013, Burton et al., 2015) and point-of-sale promotion (Wakefield et al., 2008, Kirchner et al., 2013) has been found to prompt adult smokers to buy tobacco and increase smoking frequency.

The conceptual model suggests that greater outlet density may facilitate purchases by reducing shopping time and travel costs (Pearson et al., 2014, Pearson et al., 2016). Where there are more outlets it also may be easier for adolescents to find shops willing to sell to minors and smoking norms may be more supportive of underage sales. Analysis in USA has found greater prevalence of underage tobacco sales in areas with more outlets (Lipton et al., 2008). In areas with less compliance with tobacco sales laws adolescents are more likely to initiate smoking (Pokorny et al., 2003), be current smokers (Dent and Biglan, 2004) and get cigarettes from shops (Loomis et al., 2012).

The conceptual model also indicates that tobacco outlet density may influence smoking behaviour through its effects upon retail markets. Greater competition could result in lower tobacco prices, although analysis in USA has not supported this relationship (Lipperman-Kreda et al., 2014a). There is

consistent evidence price influences youth smoking behaviour (Liang et al., 2003), including price in school localities (Lovato et al., 2013). Furthermore, competition for market share could increase retailers' willingness to sell tobacco to minors (Lipperman-Kreda et al., 2014b).

Finally, the conceptual model suggests outlet density may affect adolescent smoking behaviour through its' influence upon smoking among their family, friends and community. Links to parents' and friends' smoking behaviour may be important as it is a strong influence upon the likelihood adolescents will smoke (De Vries et al., 2003).

Study aims

This study builds on previous research in Scotland demonstrating an association between tobacco outlet density in home neighbourhoods and adolescents' smoking behaviour (Shortt et al., 2014) by assessing *how* outlet density and smoking are related. It uses path analysis to explore a selection of the potential pathways in the conceptual model, focussing upon tobacco knowledge, beliefs, purchasing behaviours and price. It aims to contribute to knowledge by comparing several pathways and using path analysis to consider both direct and indirect effects of outlets through influence upon adolescents' parents and friends smoking behaviour.

The research questions are:

1. Is tobacco outlet density in adolescents' home neighbourhood associated, after adjustment for individual and neighbourhood characteristics, with their…
    a. ...knowledge about cigarette brands?
    b. …positive beliefs about smoking?
    c. …likelihood of buying cigarettes themselves from shops?
    d. …likelihood of buying cigarettes from shops through adult proxy purchasers?

e. …reported price of cigarettes?

2. Does tobacco outlet density affect these pathways to smoking through an association with adolescents' parents and friends' smoking?
3. Do these relationships vary with adolescent smoking status?

Methods

Study setting

In Scotland the proportion of adolescents aged 13 and 15 years that were regular smokers was 2% and 9% respectively in 2013, the lowest rates recorded (ISD Scotland, 2014). These children grew up during an era of continuous tobacco restrictions. In the UK advertising and sponsorship on billboards and in printed publications were prohibited in 2003 and a ban on tobacco sponsorship of international sport was introduced in 2005. Following an EU Directive the UK introduced new larger warnings on cigarette packs in 2003, increasing the size to 30% on the front and 40% on the back and in 2008 implemented picture warnings on tobacco products. In addition, the Scottish Government has, in recent years, banned smoking in enclosed public places in 2006, raised the permitted age for tobacco sales from 16 to 18 years in 2007, made proxy tobacco purchases by adults for minors an offense and introduced compulsory registration for tobacco retailers in 2011 and banned point-of-sale tobacco advertising for large retail outlets in 2013 and all outlets in 2015.

Scottish Schools Adolescent Lifestyle and Substance Use Survey (SALSUS)

This study uses data from SALSUS, a national survey commissioned, usually biennially, by the Information Services Division (ISD Scotland) on behalf of the Scottish Government to monitor targets

for reductions in adolescent smoking, drinking and illegal drug use (Black et al., 2011). The survey is completed in Secondary 2 and 4 when pupils are mostly aged 13 and 15 years respectively. Fieldwork for the 2010 survey was conducted between September 2010 and February 2011 (NHS Scotland, 2011). When the data were collected tobacco sales to people under 18 years were illegal but the bans of proxy purchases for minors, which came into force in April 2011, and point-of-sale displays had not yet been introduced.

Nationally representative classes were sampled from the Scottish Government schools database which contains all state and independent secondary schools across Scotland, excluding schools for children with Additional Support Needs. The overall response rate, the product of the class and pupil response rate, was 62% (NHS Scotland, 2011). In total 37,307 pupils from 1,851 classes in 302 schools completed the questionnaire.

Tobacco outlet density variable

The tobacco outlet density measure describes the density of tobacco shops within 400m of the adolescents' residential postcode. UK postcodes are small areas defined by postal addresses and containing an average of 15 households. The size of buffer is smaller than that adopted in many outlet density studies including previous analysis of SALSUS (Shortt et al., 2014). It was selected because while adolescents are likely to have contact with outlets across a wider area, places closest to home may be where they spend the greatest time (Loebach and Gilliland, 2016) and have the most influence on the pathways assessed in this study.

Tobacco outlet data were downloaded from the Scottish Tobacco Retailers Register on 30 September 2012. The register contains addresses of all premises selling tobacco including newsagents, supermarkets, garage shops and vans. This dataset, after cleaning to remove vans and duplicates,

contained 10,161 tobacco outlets (Shortt et al., 2014), approximately 1.9 for every 1,000 people in Scotland in 2011.

The outlets were mapped in ArcGIS based on their postcode co-ordinates. A Kernel Density Estimation (KDE) was then used to transform these locations into a continuous surface map describing the outlet density across Scotland. This map divided Scotland into 100mx100m grid cells. For each cell the KDE value described the number and proximity of outlets within a 400m buffer radius. Outlets nearer the radius centre had a greater weight and those further away progressively less based on a decay function. Each of the 50,466 postcodes in Scotland were then linked to the map using their centroid location. KDE values representing the proximity-weighted outlets per square kilometre within a 400m buffer were extracted for each postcode.

ISD Scotland linked the KDE postcode values to the home postcode values of the SALSUS respondents. Among the 37,307 survey members 15,258 (40.9%) respondents' home postcodes were missing or could not be linked to the KDE postcodes and so were excluded from the analysis, leaving 22,049 linked respondents.

The KDE values of the SALSUS respondents included in the analysis were divided into three 'tertile' groups. The first was a zero density group comprising the 32.1% of respondents with no outlets within their 400m buffer. The remaining respondents were divided into two equally-sized groups, containing 34.0% living in 'low' and 'high' KDE value areas. This approach allowed areas without outlets to be compared to two other groups of areas containing approximately similar numbers of cases (Marsh et al., 2016),

Adolescent smoking variable

SALSUS respondents were asked 'Do you smoke cigarettes at all nowadays?' ('yes' or 'no'). Those that responded positively were defined as 'current smokers'. Respondents were also asked which statement best described their smoking behaviour: 'I have never smoked', 'I have only ever tried smoking once', 'I used to smoke sometimes but I never smoke a cigarette now', 'I sometimes smoke cigarettes now but I don't smoke as many as one a week', ' I usually smoke between one and six cigarettes a week' and ' I usually smoke more than six cigarettes a week'. All respondents who stated that they'd ever tried smoking, but were not current smokers, were categorised as 'ever smokers'. Those that had never tried smoking were 'never smokers'. A sub-group of current smokers were assessed in analysis of cigarette price (defined below).

Parent and friend smoking variables

Three parental smoking status categories were derived from responses describing mother and father's smoking behaviour (see Table 1). Friends smoking was defined by six categories describing the proportion smoking.

Brand knowledge, smoking beliefs and retail purchases and price variables

SALSUS respondents were asked to write down up to four brands of cigarettes they had 'either seen or heard of'. Due to limitations of time and cost only approximately one third of cases were selected for transcribing, described by the data provider as a random sample. The dataset provided contained counts of '1', '2', '3' or '4' brands named and a code '0' combining the responses 'none', 'don't know' or 'wrote something but not legitimate'.

Attitudes to smoking were indicated by responses to 13 statements regarding smoking behaviour, ('agree' or ' disagree'), ten of which considered potential health risks and psychological benefits of

smoking (see Table 2). These 13 items had a Cronbach's alpha of .941 indicating an excellent internal consistency. Positive smoking beliefs were therefore combined, and total counts coded for this analysis as '1', 2', '3', '4', '5', '6' and '7-13'.

Adolescents that reported smoking were asked 'Where do you usually get your cigarettes from?' Those that stated one or more of the sources 'a supermarket', 'a newsagent, tobacconist or a sweet shop', a 'garage shop' or 'other shop' were defined as purchasing from shops. Adolescents were defined as making proxy purchases if they stated that usually 'I ask an adult I don't know to buy me cigarettes/tobacco from a shop'. The purchasing variables were assessed as dichotomous yes/no outcomes.

Tobacco price was measured using a question asking how much a packet of twenty cigarettes cost in pounds and pence. In this analysis these price estimates were intended to provide an indication of market cost, so the price variable focussed on smokers that were likely to have the most accurate recall of prices. Responses from current smokers that had not purchased cigarettes from a shop within the last four weeks, 1377 cases or 64.9% of all current smokers, were therefore excluded from the analysis, leaving 746 cases. Current smokers that had recently purchased cigarettes but did not suggest a 'realistic' price were also excluded. At the time of the survey fieldwork cigarette prices in Scotland averaged £6.29 for a packet of twenty, with most cheap brands costing £5.00-£6.00 (Black et al., 2011). Responses outside £4.00-£6.99, 178 or 23.9% of the remaining cases were excluded. Models assessed price as a continuous variable.

Sociodemographic and neighbourhood variables

The adolescents were categorised by their sex, age and ethnic group (combined into 'white British' and 'black and minority ethnic'). The economic status of adolescents' families was measured using a

question regarding how 'well off' they perceived their family to be. Family structure was categorised in this analysis as either 'both parents' or 'one parent/other'.

Neighbourhood deprivation was defined using Scottish Index of Multiple Deprivation (SIMD) scores for data zones (500-1,000 household residents in 2001) grouped into quintiles for all Scotland. Urban/rural status of neighbourhoods was defined for data zones by the six categories in the Scottish Government Urban Rural Classification (see Table 1).

Analytic strategy

Path models were used to assess the relationship between the density of registered tobacco outlets near adolescents' homes and each of the tobacco knowledge, beliefs and retail purchases and prices reported in SALSUS. All analyses were stratified by adolescent smoking status.

Path analysis

Path analysis is a type of structural equation modelling which explores correlations within a defined network. It can test whether an a priori causal model of multivariate relationships fits a dataset. Path models, despite their potential, have rarely been used in epidemiological research (Tu, 2009) with few examples of smoking analyses (e.g. Grant et al., 2008). We used this novel approach as it could test a complex model of relationships, including direct and indirect relationships.

Hypothesised model

The hypothesised model used to predict the tobacco knowledge, beliefs and retail purchase and price variables in the path analysis is described in Figure 2. Straight line arrows indicate the direction

of proposed causal effects and two-headed, curved arrows represent correlations. This model hypothesises there is a direct relationship between outlet density and the tobacco knowledge, beliefs and retail purchase and price variables. It is also hypothesised that outlet density has indirect effects on these outcomes through its' influence upon parent and friend smoking. It is suggested that the tobacco knowledge, beliefs and retail variables are directly affected by the respondents' sex, age, ethnic group, family wealth, family structure ('one parent') and by their neighbourhoods' urban/rural status ('urban') and SIMD quintile ('deprivation'). Urban/rural status and deprivation have direct effects upon outlet density and parent and friend smoking. Family structure and ethnic group are also hypothesised to have direct effects upon parent's smoking. While adolescents' age and sex have direct effects on friends smoking. Finally, the model hypothesises that there are correlations between the pairs of variables; deprivation-urban/rural status, deprivation-family wealth, deprivation-family structure and urban/rural status-ethnic group.

Estimation model and goodness of fit tests

The path analysis was conducted using AMOS 19. As most variables were ordinal or categorical, the standard maximum likelihood estimation approach was not appropriate (Kline, 2005). Asymptomatic distribution free (ADF) estimation was adopted for most models as it does not make distributional assumptions (Muthen, 1993). The models for the binary (yes/no) shop purchase variables were estimated using the Markov Chain Monte Carlo (MCMC) Bayesian bootstrapping approach which can support binary outcomes in AMOS. Models excluded all cases with missing data.

Model fit was evaluated, as recommended, using a range of indices to assess absolute, parsimony adjusted and comparative fit (Hooper et al., 2008). As sample size can inflate the chi-square statistics, we report the χ^2/d.f. ratio and the root-mean-squared residual (SRMR) as the measure of overall goodness of fit (degrees of freedom for all the models presented were 28). The root-mean-squared-

error (RMSEA) of approximation was the selected parsimony adjusted index. The comparative fit was assessed by the comparative fit index (CFI). The cut-offs adopted as indicators of acceptable fit were <3.0 for χ^2/d.f., <0.06 for RMSEA, >0.90 for CFI and <0.08 for SRMR (Hu and Bentler, 1999). Goodness of fit measures cannot however be produced in AMOS for models estimated using MCMC bootstrapping.

Results

Characteristics of sample

Among the 22,049 13 and 15 year olds in the analysis 9.6% were current smokers, 18.1% ever smokers and 71.1% never smokers (Table 1). Current and ever smokers', in comparison to never smokers, were more likely to live in high outlet density areas and less likely in zero density areas. Smokers were also more likely to live in the most deprived quintile of neighbourhoods.

Among current and ever smokers 58.1% and 44.9%, respectively, stated one or more of their parents smoked daily compared to 24.6% of never smokers. Just 1.5% and 13.7% of current and ever smokers, respectively, had no friends who smoked in contrast to 52.4% of never smokers. Current smokers were also more likely to be older, female and living in a one parent/other family.

Frequency of brand knowledge, smoking beliefs and retail purchase and price variables

More than four-fifths of adolescents could name one or more cigarette brands in all smoking status groups (Table 2). The proportion that could name four brands was 10.1%, 29.7% and 63.8% among never, ever and current smokers respectively. All statements regarding health harms of smoking were supported by the majority of children in each smoking group. Current and ever smokers

however responded more positively, relative to never smokers, to all statements about smoking with 37.4% current and 18.0% ever smokers holding four or more positive beliefs compared to only 8.8% of never smokers.

Among current smokers 36.3% stated they usually bought cigarettes from shops (Table 3). The most common type of shop, indicated by 30.4%, was a newsagent, tobacconist or sweet shop. In the last four weeks 35.1% of current smokers had bought cigarettes from a shop, supermarket or van and 6.3% had tried unsuccessfully. A smaller proportion of adolescents acquired cigarettes from shops through proxies with 23.5% stating that they usually requested adult strangers buy for them.

The adolescents gave a large range of estimated prices for a packet of 20 cigarettes, from 10 pence to over £800. Current smokers however mostly suggested estimated prices within the range of £4.00 to £6.99 with a mean price of £5.83 (SD=£11.67).

Path models

The standardised direct effects for all variables in the hypothesised model are described in Table 4. In addition, for outlet density standardised indirect and total effects and unstandardized direct, indirect and total effects are also described.

The path models indicated that outlet density did not have significant ($p<.05$) direct effects upon the knowledge, beliefs and retail purchase and price variables with the exception of knowledge of cigarette brands among never smokers. The model containing this significant result is presented in Figure 3. This model suggests that higher outlet density was associated with moderately greater knowledge of cigarette brands, with significant standardised direct effects of 0.05 among never smokers. This indicates that if the outlet density category increased by one standard deviation from its mean the number of brands named by never smokers would be expected to increase by 0.05 of its

own standard deviation from its own mean, holding all other path connections constant (mean=1.60; standard deviation=1.18; range=4.00). While the un-standardised direct effect of outlet density upon brand knowledge of 0.07 indicates that for each increase in outlet density 'tertile' the number of brands never smokers could name would be expected to increase by 0.07. A similar size standardised direct effect of outlet density on brand knowledge was found among ever and current smokers but was not statistically significant. The expected association between outlet density and cigarette price was also found, indicating cigarettes were cheaper in areas with more outlets, but was weak and not significant.

Outlet density had small, significant, direct effects upon parents' smoking behaviour in models of brand name among current smokers, positive beliefs among never and current smokers and buying tobacco from shops among current smokers, for themselves and through proxies. In addition, outlet density had significant effects upon the likelihood adolescents' friends smoked in models of current smokers' beliefs about smoking and shop purchases of cigarettes for themselves and through proxies.

Parent and friend smoking in turn had strong influences on some of the knowledge, beliefs and retail purchase variables. Both parent and friend smoking had significant direct effects on brand knowledge among adolescents with parents' smoking having a relatively greater influence among never smokers and friends' smoking among current smokers. In models of positive smoking beliefs friend smoking was found to have significant direct effects on all smoker groups and parent smoking on never and current smokers. Friends' smoking also had strong direct effects on the likelihood that current smokers reported buying cigarettes for themselves from shops or through proxies.

Outlet density had indirect effects upon some knowledge, beliefs and retail purchase and price variables though effects on parent and friend smoking but these effects were small, with the largest

standardised indirect effect of outlet density of just 0.03 found in the model of brand names among current smokers. The greatest total standardised effects of outlet density, combining direct and indirect effects, found among the knowledge, beliefs and retail variables were also for brand names, but were modest at 0.05, 0.06 and 0.08 among never, ever and current smokers respectively.

The models indicated that neighbourhood deprivation and urban/rural status influenced more of the knowledge, beliefs and retail variables than outlet density. Deprivation had direct effects on adolescent's brand knowledge, with significantly more brands named by never and current smokers in deprived neighbourhoods. However, adolescents in deprived areas had significantly fewer positive beliefs about smoking in all smoker groups. Adolescents in more deprived areas were more likely to have acquired cigarettes through a proxy purchase. Deprivation was also significantly negatively associated with cigarette price indicating adolescents in deprived areas reported cigarettes were cheaper. Urban status had strong significant direct effects on both tobacco purchases by adolescents from shops for themselves and through proxies.

The models also found significant direct effects of adolescent age and sex on the knowledge, beliefs and retail purchase variables, with greater brand knowledge, more positive smoking beliefs and more purchases from shops among older adolescents and boys. Family wealth and structure did not have significant effects upon most of the knowledge, beliefs and retail variables.

All models met *a priori* model fitting criteria for RMSEA and SRMR. However, the CFI thresholds were narrowly missed in the models for brand knowledge and positive smoking beliefs of ever and current smokers, and by a larger margin for price among current smokers. Notably, the model in which outlet density was found to have a significant direct effect upon brand knowledge among never smokers met all the RMSEA, SRMR and CFI thresholds.

None of the models met the p value criteria. The relatively large sample sizes in the models meant it was perhaps unlikely they would achieve this. In addition, only the models with the smallest sample size (<600), brand name knowledge and cigarette price among current smokers, met the $\chi 2/d.f.$ threshold, which is also sensitive to sample size (Iacobucci, 2010).

Discussion

The strongest evidence of association between tobacco outlet density and the pathways to smoking examined was found for cigarette brand knowledge. Adolescent never, ever and current smokers living in high density areas had moderately greater brand knowledge compared to those in lower density areas, a relationship which was statistically significant among never smokers. Analysis of brand knowledge among current smokers also suggested outlet density can have small indirect effects on adolescents' pathways to smoking through influence on their parents' and friends' smoking behaviour. However, adolescents in higher outlet density areas did not have more positive smoking beliefs in any smoker group and current smokers were not more likely to buy tobacco from shops themselves or through proxies. Adolescent smokers in higher outlet density areas did report cigarettes were slightly cheaper, but not significantly.

Adolescents' awareness of tobacco products and pathways to smoking

Previous analysis has found adolescents' cigarette brand knowledge was associated with shop visits (Van Der Sluijs et al., 2016, Dauphinee et al., 2013) but the authors' believe this is the first study to indicate a relationship with shop density. A similar strength of association between density and brand knowledge was found for all smoker groups, and was significant among never smokers, suggesting brand awareness was not driven by tobacco purchases but could have resulted from more passive exposure to outlets.

The conceptual model hypothesised that awareness of tobacco products may affect beliefs about smoking and prompt tobacco purchases. However, this study did not find outlet density was related to adolescents' smoking beliefs or purchasing behaviour. Therefore, while the analysis suggests outlet density could increase adolescents' tobacco product knowledge it does not indicate how this may support smoking.

Adolescent smoking beliefs, social norms and family and friend smoking

The finding that outlet density had no effects upon smoking beliefs differed from previous research. Outlet density may affect different types of smoking beliefs in distinctive ways (Schleicher et al., 2016). Previous outlet studies have focussed upon beliefs that smoking is prevalent (Schleicher et al., 2016) and makes people 'cool' and 'fit in' (Loomis et al., 2012). In contrast, our beliefs measure primarily focussed on health and psychological effects of smoking. Outlet density could affect smoking beliefs primarily by shaping understanding of behavioural norms. The potential disjuncture between the smoking beliefs measure used in this analysis and behavioural norms is perhaps supported by analysis of deprivation. Adolescents in more deprived areas had fewer positive beliefs about smoking yet current smokers in these areas reported more proxy tobacco purchases, suggesting local behavioural norms supporting smoking (Robinson and Amos, 2010, Donaghy et al., 2013).

The importance of behavioural norms is also suggested by the strong influence of parent and friend smoking found upon adolescents' tobacco knowledge, beliefs and retail purchases. Analysis of the relationship between outlet density and adolescent smoking has typically conceived family and friend's smoking behaviour as confounding variables (e.g. Shortt et al., 2014), however, they may be mediators through which outlets influence adolescents.

Research assessing the hypothesis that tobacco outlets normalise smoking may also need to conceive more fully what 'normalisation' represents at this stage of the smoking pandemic in Scotland when smoking is a highly socioeconomically stratified (Hiscock et al., 2012) and stigmatised (Hammond et al., 2006) minority behaviour. In this analysis fewer than 10% of adolescents were current smokers and many negative beliefs about smoking were broadly held, with more than 90% in all smoker groups agreeing that smoking causes lung cancer and makes clothes smell. The continuing high street presence of tobacco retail may have limited influence on adolescent perceptions of the social acceptability of smoking compared to the social stigmatisation of smoking (Bell et al., 2010, Barnett et al., 2017) or their family and friends smoking behaviour (De Vries et al., 2003).

Tobacco purchasing and market competition

This study found adolescents in outlet dense areas were not more likely to report buying cigarettes from shops. Previous research indicating that exposure to tobacco outlets prompts tobacco purchases has focussed on adults (Burton et al., 2013). Minors are less likely to acquire tobacco from shops and may make fewer impulse purchases because planning is required to locate retailers and proxy buyers willing to facilitate sales to minors (Donaghy et al., 2013, Ng et al., 2014). The strong association found between urban neighbourhoods and adolescents' cigarette purchases, for themselves and though proxies, suggests that area characteristics that influence purchases may be those supporting illegal sales by reducing social controls.

As in previous USA analysis of cigarette purchase prices (Lipperman-Kreda et al., 2014a) this study of estimated cigarette prices did not find a significant association between outlet density and price, although reported prices in higher density areas were lower. However, cigarette price was found to

be strongly associated with deprivation (Burton et al., 2014, Lipperman-Kreda et al., 2014a), perhaps further evidence that area characteristics can influence price.

Tobacco outlet policy

Recent proposals to restrict tobacco outlets have focussed upon varying pathways to smoking (Ackerman et al., 2016, Pearson et al., 2014, Pearson et al., 2016). Some policies, such as outlawing sales in pharmacies in USA (already banned in UK), centre upon social norms, while others restricting total numbers or distance between outlets, focus more widely upon contact with retail. The small positive associations found in this analysis between outlet density and brand knowledge perhaps provide more support for broad reductions in outlets.

Although the association found between outlet density and brand knowledge was small, tobacco control in high-income nations increasingly aims to make marginal gains from multiple interventions (Barnett et al., 2017), so small affects upon tobacco product knowledge could still contribute. The recent ban on tobacco point-of-sale displays within shops in Scotland could reduce effects of outlets upon tobacco knowledge. Conversely, outlets themselves may now play a relatively greater role as environmental influences (Burton et al., 2015). Further analysis could assess the impacts of Scottish bans on point-of-sale promotion and proxy sales for minors. Finally, this analysis reiterates the importance of parents' smoking behaviour for adolescents and suggests that policies to reduce adult smoking, including those focussed on tobacco retail outlets, may decrease adolescent smoking.

Methodological strengths and limitations

This study used a novel approach, path analysis, to assess the direct and indirect relationships between tobacco outlet density and a range of potential pathways to adolescent smoking. The

analysis benefited from complete records of registered tobacco retail outlets in Scotland and data from SALSUS, a large scale, high-quality survey. SALSUS data also had some limitations in this analysis. More than 40% of SALSUS respondents did not provide a home postcode and had to be excluded from the analysis. Comparison of the adolescent smoker and sociodemographic characteristics of the included and excluded cases indicates that there were significant differences ($p>0.001$) in smoker status, sex, family structure and wealth. Excluded cases were more likely to be current smokers (16.5% v 9.7%), ever smokers (21.5% v 18.3%), male (54.1% V 48.5%), in one parent/other families (35.8% v 29.9%) and to be not well off/not at all well off (6.4% v 5.7%).

The adolescent smoking behaviour questions contained in SALSUS, while frequently in UK health surveys, differ from those most commonly adopted in smoking studies in other countries, limiting international comparisons. SALSUS coded only a minority of cigarette brand responses. Adolescents' responses regarding cigarette prices may not have represented neighbourhood costs. The survey's family wealth measure may have self-report biases. SALSUS did not record the addresses of adolescents' parents or friends, so it was assumed they shared the adolescents' residential exposures.

Most SALSUS variables assessed in the path models were categorical not continuous. Some models did not meet CFI thresholds. All outcomes and smoker groups used the same hypothesised model. Model fit could have been improved by using models customised for each group separately.

The study found less evidence of association between tobacco outlets and pathways to smoking than some previous research. This could be because these analyses were completed in different contexts, often within regions and cities in USA (Gwon et al., 2016) rather than at a national level in Scotland. Previous analysis in Scotland indicated the strength of association between outlet density and adolescent smoking behaviour was modest and non-linear, finding particularly low risk of smoking in

areas with no outlets (Shortt et al., 2014). The ubiquity of tobacco outlets in Scotland, may make identification of their effects difficult, especially in urban areas. The density of Scottish tobacco outlets found in this study of 1.9 per 1,000 people was considerably higher than that of 1.3 per 1,000 found, for example, in the USA (Lee et al., 2017)

This analysis focussed upon outlets near adolescent's homes. However, measures of exposure to tobacco outlets around home and schools may underestimate adolescents' exposures (Lipperman-Kreda et al., 2015). Other 'activity spaces' used for work and recreation may have greater outlet concentrations (Kwan, 2009, Shareck et al., 2015).

This study explored only a selection of the pathways hypothesised in the conceptual model and assessed them in separate models not in combination. It didn't consider the association between the pathways and adolescent smoking behaviour because, like most studies in this field, it was limited by cross-sectional data (Gwon et al., 2016). Some pathways in the conceptual model, such as tobacco knowledge and smoking beliefs, may have bi-directional relationships with smoking, so longitudinal data would be required to assess them. This analysis therefore represents one more step towards a fuller exploration of the pathways outlined in the conceptual model.

Conclusion

This study is the first to demonstrate an association between outlet density and adolescents' knowledge of cigarette brands. Exposure to tobacco outlets may influence adolescents' awareness of tobacco products, a possible pathway to smoking, and so reductions in outlet density could form part of multifactorial approaches to tobacco control.

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Tables

Table 1. Descriptive statistics: sociodemographic and area variables

Sociodemographic and area variables	Total		Adolescent smoking status					
			Never smoker		Ever smoker		Current smoker	
	N	%	N	%	N	%	N	%
All adolescents	22049	100	15684	100	4001	100	2123	100
Adolescent smoking status								
Never smoked	15684	71.1	-	-	-	-	-	-
Ever smoked	4001	18.1	-	-	-	-	-	-
Current smoker	2123	9.6	-	-	-	-	-	-
Not stated	241	1.1	-	-	-	-	-	-
Tobacco outlet density tertile								
Zero density	7067	32.1	5338	34.0	1082	27.0	583	27.5
Low density	7491	34.0	5322	33.9	1374	34.3	694	32.7
High density	7491	34.0	5024	32.0	1545	38.6	846	39.8
Age								
13 years (Secondary 2)	11532	52.3	9463	60.3	1462	36.5	440	20.7
15 years (Secondary 4)	10517	47.7	6221	39.7	2539	63.5	1683	79.3
Sex								
Female	11338	51.4	7991	51.0	2031	50.8	1209	56.9
Male	10684	48.5	7679	49.0	1963	49.1	908	42.8
Not stated	27	0.1	14	0.1	7.0	0.2	6.0	0.3
Ethnicity								
White British	19657	89.2	14075	89.7	3554	88.8	1833	86.3
Black and minority ethnic group	2163	9.8	1481	9.4	390	9.7	253	11.9
Don't know/not stated	229	1.0	128	0.8	57	1.4	37	1.7
Self-perceived family wealth								
Very well off	2216	10.1	1652	10.5	339	8.5	197	9.3
Quite well off	8591	39.0	6460	41.2	1376	34.4	666	31.4
Average	9113	41.3	6242	39.8	1792	44.8	981	46.2
Not well off/not at all well off	1205	5.5	735	4.7	295	7.4	167	7.9

Not stated	924	4.2	595	3.8	199	5.0	112	5.3
Family structure								
Both parents	15044	68.2	11403	72.7	2363	59.1	1108	52.2
One parent/other	6597	29.9	4013	25.6	1549	38.7	970	45.7
Not stated	408	1.9	268	1.7	89	2.2	45	2.1
Parental smoking status								
Both parents don’t smoke	11603	52.6	9326	59.5	1587	39.7	579	27.3
One or more parent smoke occasionally	1745	7.9	1240	7.9	337	8.4	145	6.8
One or more parents smokes daily	6965	31.6	3865	24.6	1796	44.9	1234	58.1
Not stated/unknown/child doesn't have parent or carer	1736	7.8	1253	8.0	281	7.0	165	7.8
Smoker friends								
None	8905	40.4	8220	52.4	550	13.7	32	1.5
Almost none	6142	27.9	4714	30.1	1228	30.7	143	6.7
Less than half	3347	15.2	1791	11.4	1132	28.3	393	18.5
Half	1335	6.1	448	2.9	504	12.6	370	17.4
More than half	1250	5.7	242	1.5	377	9.4	620	29.2
All or almost all	791	3.6	86	0.5	152	3.8	551	26.0
Not stated	279	1.3	183	1.2	58.0	1.4	14	0.7
Urban/rural status								
Remote rural	1989	9.0	1384	8.8	368	9.2	224	10.6
Accessible rural	2979	13.5	2129	13.6	513	12.8	302	14.2
Small remote towns	1075	4.9	752	4.8	198	4.9	115	5.4
Small accessible towns	2105	9.5	1481	9.4	396	9.9	213	10.0
Other urban	7347	33.3	5199	33.1	1352	33.8	704	33.2
Large urban areas	6513	29.5	4710	30.0	1168	29.2	559	26.3
Missing	41	0.2	29	0.2	6	0.1	6	0.3
Deprivation quintile								
1 (least deprived)	5269	23.9	4175	26.6	722	18.0	326	15.4
2	4948	22.4	3642	23.2	812	20.3	446	21.0
3	4777	21.7	3382	21.6	874.0	21.8	468	22.0
4	4018	18.2	2663	17	833	20.8	478	22.5
5 (most deprived)	3030	13.7	1818	11.6	758	18.9	404	19.0

Missing	7	0.0	4	0.0	2	0.0	1	0.0

Table 2. Descriptive statistics: tobacco knowledge and smoking beliefs variables

Tobacco knowledge and smoking beliefs variables		Total		Adolescent smoking status					
				Never smoker		Ever smoker		Current smoker	
		N	%	N	%	N	%	N	%
All adolescents		22049	100	15684	100	4001	100	2123	100
Number of cigarette brands named									
Coded cases: Total		6280	28.5	4297	27.4	1238	30.9	679	32.0
0 - none/don't know/response not legitimate		758	3.4	688	4.4	57	1.4	9	0.4
1		2079	9.4	1720	11.0	279	7.0	55	2.6
2		1392	6.3	992	6.3	293	7.3	91	4.3
3		807	3.7	463	3.0	241	6.0	91	4.3
4		1244	5.6	434	2.8	368	9.2	433	20.4
Uncoded cases: Total		15769	71.5	11387	72.6	2763	69.1	1444	68.0
Number of positive smoking beliefs									
0		3540	16.1	3131	20	311	7.8	59	2.8
1		5645	25.6	4456	28.4	908	22.7	235	11.1
2		5276	23.9	3729	23.8	1056	26.4	444	20.9
3		3205	14.5	2028	12.9	736	18.4	405	19.1
4		1724	7.8	925	5.9	420	10.5	356	16.8
5		698	3.2	302	1.9	181	4.5	207	9.8
6		293	1.3	99	0.6	69	1.7	118	5.6
7-13		218	1.0	55	0.4	51	1.3	110	5.2
Missing		1450	6.6	959	6.1	269	6.7	189	8.9
Smoking beliefs by type									
Smoking gives people confidence	Agree	4174	18.9	2580	16.4	901	22.5	650	30.6
	Disagree	17480	79.3	12852	81.9	3021	75.5	1428	67.3
	Missing	395	1.8	252	1.6	79	2.0	45	2.1
Smoking makes people worse at sports									
	Agree	19010	86.2	13733	87.6	3434	85.8	1645	77.5
	Disagree	2756	12.5	1769	11.3	514	12.8	449	21.1
	Missing	283	1.3	182	1.2	53	1.3	29	1.4

Smokers stay slimmer than non-smokers	Agree	6631	30.1	4338	27.7	1413	35.3	807	38.0
	Disagree	14913	67.6	11003	70.2	2501	62.5	1260	59.3
	Missing	505	2.3	343	2.2	87	2.2	56	2.6
If a women smokes when she is pregnant, it can harm her unborn baby	Agree	21155	95.9	15179	96.8	3817	95.4	1940	91.4
	Disagree	673	3.1	375	2.4	133	3.3	159	7.5
	Missing	221	1.0	130	0.8	51	1.3	24	1.1
Smoking helps people relax if they feel nervous	Agree	13863	62.9	8945	57	2952	73.8	1827	86.1
	Disagree	7778	35.3	6464	41.2	970	24.2	262	12.3
	Missing	408	1.9	275	1.8	79	2.0	34	1.6
Smoking can cause heart disease	Agree	20032	90.9	14431	92.0	3566	89.1	1834	86.4
	Disagree	1688	7.7	1053	6.7	363	9.1	250	11.8
	Missing	329	1.5	200	1.3	72	1.8	39	1.8
Smoking is not really dangerous, it only harms people that smoke a lot	Agree	3668	16.6	1892	12.1	965	24.1	766	36.1
	Disagree	18052	81.9	13582	86.6	2975	74.4	1318	62.1
	Missing	329	1.5	210	1.3	61	1.5	39	1.8
Smokers get more coughs and colds than non-smokers	Agree	18826	85.4	13706	87.4	3339	83.5	1591	74.9
	Disagree	2862	13	1752	11.2	590	14.7	487	22.9
	Missing	361	1.6	226	1.4	72	1.8	45	2.1
Other people's smoking can harm the health of non-smokers	Agree	20782	94.3	14949	95.3	3748	93.7	1877	88.4
	Disagree	946	4.3	543	3.5	185	4.6	203	9.6
	Missing	321	1.5	192	1.2	68	1.7	43	2.0
Smoking helps people cope better with life	Agree	3072	13.9	1576	10	711	17.8	744	35.0
	Disagree	18560	84.2	13859	88.4	3205	80.1	1314	61.9
	Missing	417	1.9	249	1.6	85	2.1	65	3.1
Smoking makes your clothes smell	Agree	21281	96.5	15229	97.1	3841	96.0	1997	94.1

	Disagree	515	2.3	309	2.0	103	2.6	93	4.4
	Missing	253	1.1	146	0.9	57	1.4	33	1.6
Smokers are more fun than non-smokers									
	Agree	810	3.7	268	1.7	185	4.6	349	16.4
	Disagree	20853	94.6	15192	96.9	3732	93.3	1717	80.9
	Missing	386	1.8	224	1.4	84	2.1	57	2.7
Smoking can cause lung cancer	Agree	21558	97.8	15423	98.3	3891	97.3	2021	95.2
	Disagree	258	1.2	136	0.9	48	1.2	72	3.4
	Missing	233	1.1	125	0.8	62	1.5	30	1.4

Table 3. Descriptive statistics: retail purchases and price variables

Retail purchase and price variables	Adolescent smoking status	
	Current smoker	
	N	%
All adolescents	2123	100
Usually buys cigarettes/tobacco for self from a shop		
Yes - buys for self from shops - total	770	36.3
- newsagent, tobacconist or sweet shop	645	30.4
- supermarket	194	9.1
- a garage shop	152	7.2
- other type of shop	80	3.8
No - does not buy for self from shops	1274	60.0
Missing	79	3.7
Note: Adolescents could state more than one cigarettes/tobacco shop source so categories do not sum to total.		
Usually asks an adult stranger to buy cigarettes/tobacco from a shop		
Yes - buys from shops though proxy purchasers	498	23.5
No - does not buy from shops through proxy purchasers	1546	72.8
Missing	79	3.7
Attempts to buy cigarettes/tobacco from a shop, supermarket or van in the last 4 weeks		
Yes - bought	746	35.1
Yes - tried to buy but was refused	135	6.4
No - did not buy or try to buy	501	23.6
No - has never tried to buy	644	30.3
Missing	97	4.6
Cost of packet of 20 cigarettes		
Under £3.00	80	3.8
£3.00 to 3.99	70	3.3
£4.00 to 4.99	250	11.8
£5.00 to 5.99	1325	62.4
£6.00 to 6.99	202	9.5

£7.00 to 9.99	44	2.1
£10.00 and over	43	2.0
Missing	109	5.1

Table 4. Path model coefficients and fit statistics

Coefficient type	Variables			Tobacco knowledge, beliefs, retail purchases and price and smoking status																				
				Number of brand named						Number of positive beliefs						Shop buy		Proxy buy		Low price				
				Never smoker		Ever smoker		Current smoker		Never smoker		Ever smoker		Current smoker		Current smoker		Current smoker		Current smoker - Recent purchase				
Standardised direct effects	Outlet density	>	Tobacco knowledge, beliefs, retail purchases and price	0.05	*	0.05		0.05		0.00		0.00		0.00		-0.01		-0.03		-0.04				
** Significant at 0.05 level*	Outlet density	>	Parent smoking	0.02		0.01		0.08	*	0.04	*	0.02		0.10	*	0.10	*	0.10	*	0.09				
	Outlet density	>	Friend smoking	0.00		0.04		0.04		0.01		-0.01		0.07	*	0.08	*	0.08	*	0.01				
	Friend smoking	>	Tobacco knowledge, beliefs, retail purchases and price	0.14	*	0.19	*	0.28	*	0.13	*	0.12	*	0.12	*	0.25	*	0.22	*	0.04				
	Parent smoking	>	Tobacco knowledge, beliefs, retail purchases and price	0.22	*	0.19	*	0.13	*	0.07	*	0.01		0.06	*	0.04		-0.01		0.08				
	Family poor	>	Tobacco knowledge, beliefs, retail purchases and price	-0.03		-0.02		0.00		0.04	*	0.00		-0.02		-0.01		-0.02		0.05				
	One parent	>	Tobacco knowledge, beliefs, retail purchases and price	0.02		0.01		0.02		0.00		0.00		0.00		0.01		0.05		-0.03				
	Sex male	>	Tobacco knowledge, beliefs, retail purchases and price	0.12	*	0.12	*	0.13	*	0.03	*	0.05	*	0.06	*	0.07	*	0.04		0.05				
	Age	>	Tobacco knowledge, beliefs, retail purchases and price	0.10	*	0.16	*	0.11	*	0.05	*	0.01		-0.05	*	0.10	*	-0.03		0.04				
	Deprivation	>	Tobacco knowledge, beliefs, retail purchases and price	0.10	*	0.05		0.13	*	-0.02	*	-0.05	*	-0.05	*	-0.03		0.11	*	-0.18	*			
	Urban	>	Tobacco knowledge, beliefs, retail purchases and price	0.07	*	0.03		-0.15	*	0.02		-0.02		-0.02		0.24	*	0.15	*	0.00				
	Minority ethnic	>	Tobacco knowledge, beliefs, retail purchases and price	-0.02		-0.01		-0.07		0.04		0.04	*	0.04		-0.03		-0.04		-0.06				
	Deprivation	>	Outlet density	0.29	*	0.24	*	0.22	*	0.29	*	0.29	*	0.29	*	0.27	*	0.27	*	0.31	*			
	Urban	>	Outlet density	0.22	*	0.28	*	0.27	*	0.24	*	0.23	*	0.19	*	0.19	*	0.19	*	0.19	*			
	Deprivation	>	Parent smoking	0.20	*	0.28	*	0.27	*	0.21	*	0.25	*	0.27	*	0.25	*	0.25	*	0.18	*			
	Urban	>	Parent smoking	-0.01		-0.02		-0.03		0.01		-0.01		-0.01		-0.01		-0.01		-0.06				
	Deprivation	>	Friend smoking	0.07	*	0.10	*	0.26	*	0.07	*	0.09	*	0.20	*	0.17	*	0.17	*	0.18				
	Urban	>	Friend smoking	-0.03		-0.02		0.10	*	0.01		0.01		0.04		0.05	*	0.05	*	-0.04	*			
	Family poor	>	Parent smoking	0.14	*	0.07		0.09	*	0.10	*	0.07	*	0.10	*	0.09	*	0.09	*	0.03				
	One parent	>	Parent smoking	0.13	*	0.16	*	0.12	*	0.13	*	0.11	*	0.11	*	0.13	*	0.13	*	0.08	*			
	Sex male	>	Friend smoking	0.05	*	-0.01		0.01		0.07	*	-0.02		-0.03		-0.02		-0.02		-0.02				
	Age	>	Friend smoking	0.29	*	0.22	*	0.18	*	0.28	*	0.18	*	0.18	*	0.15	*	0.15	*	0.16	*			
Standardised indirect effects	Outlet density	>	Tobacco knowledge, beliefs, retail purchases and price	0.00		0.01		0.03		0.01		0.00		0.01		0.02		0.02		0.01				
Standardised total effects	Outlet density	>	Tobacco knowledge, beliefs, retail purchases and price	0.05		0.06		0.09		0.01		0.00		0.02		0.01		-0.02		-0.03				
Unstandardised direct effects	Outlet density	>	Tobacco knowledge, beliefs, retail purchases and price	0.07		0.08		0.06		0.00		0.01		0.00		-0.02		-0.04		-0.02				
Unstandardised indirect effects	Outlet density	>	Tobacco knowledge, beliefs, retail purchases and price	0.01		0.02		0.02		0.00		0.00		0.03		0.03		0.02		0.00				

Unstandardised total effects	Outlet density	>	Tobacco knowledge, beliefs, retail purchases and price	0.08		0.10		0.07		0.01		0.00		0.03		0.01	-0.02	-0.02	
N				3,763		1,096		589		12,893		3,263		1,678		1,758	1,758	568	
Model fit	χ^2/d.f.			5.168		3.529		2.406	†	13.897		6.438		4.386		-	-	2.898	†
† Above model fit threshold	P			0.000		0.000		0.000		0.000		0.000		0.000		-	-	0.000	
	RMSEA			0.033	†	0.048	†	0.049	†	0.032	†	0.041	†	0.045	†	-	-	0.058	†
	SRMR			0.023	†	0.042	†	0.046	†	0.022	†	0.032	†	0.035	†	-	-	0.053	†
	CFI			0.939	†	0.895		0.872		0.929	†	0.887		0.859		-	-	0.740	

Figure captions

Figure 1. Conceptual model of the potential causal pathways though which tobacco outlets density in adolescents' home area may influence smoking behaviour

Figure 2. Path diagram for the hypothesised model predicting tobacco knowledge, beliefs and retail purchase and price variables

Figure 3. Path model of standardised direct effects of outlet density upon number of cigarette brands named by never smokers

Figure 1.

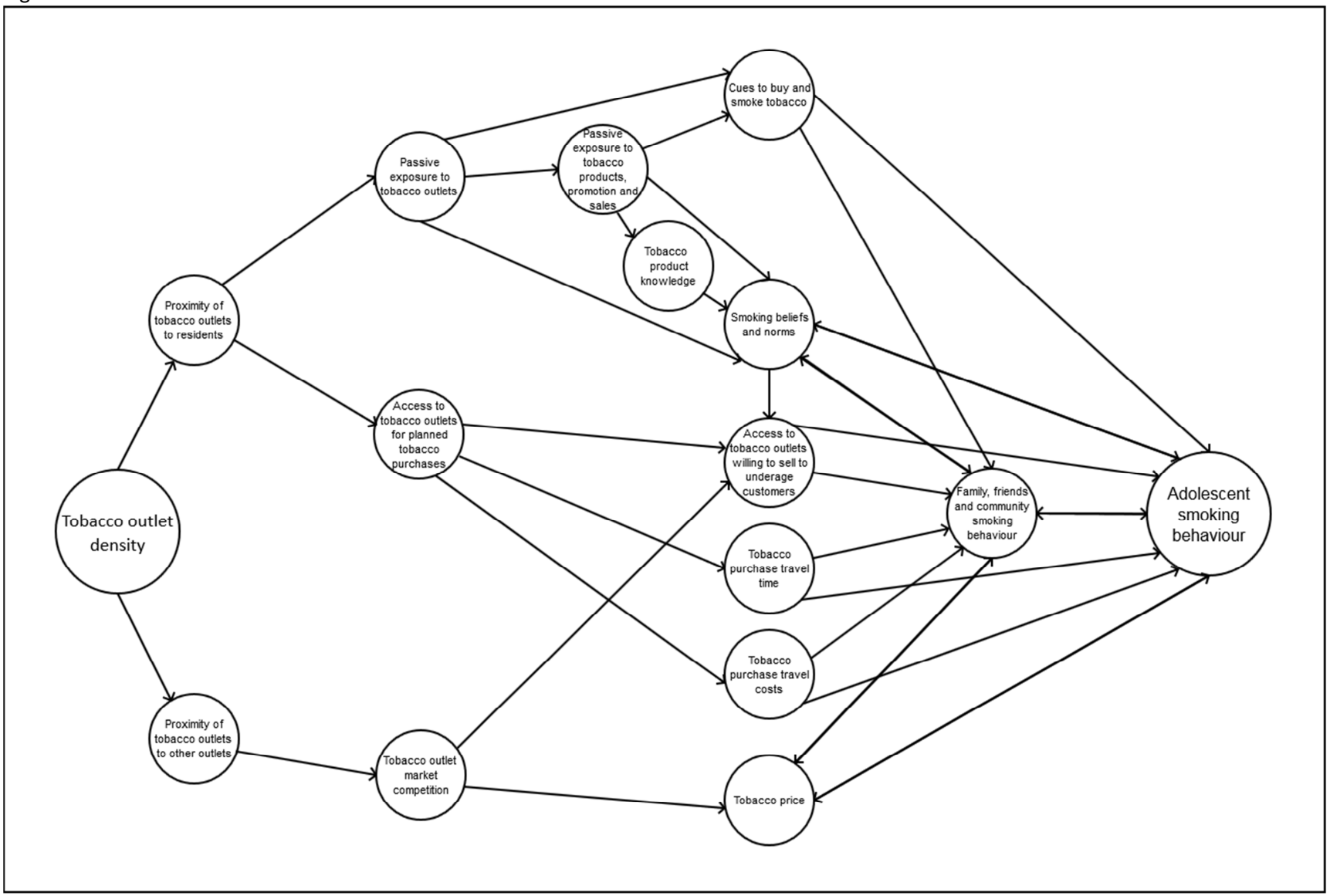

Cues to buy and smoke tobacco
Passive exposure to tobacco outlets
Passive exposure to tobacco products, promotion and sales
Tobacco product knowledge
Proximity of tobacco outlets to residents
Smoking beliefs and norms
Access to tobacco outlets for planned tobacco purchases
Access to tobacco outlets willing to sell to underage customers
Tobacco outlet density
Family, friends and community smoking behaviour
Adolescent smoking behaviour
Tobacco purchase travel time
Tobacco purchase travel costs
Proximity of tobacco outlets to other outlets
Tobacco outlet market competition
Tobacco price

Figure 2.

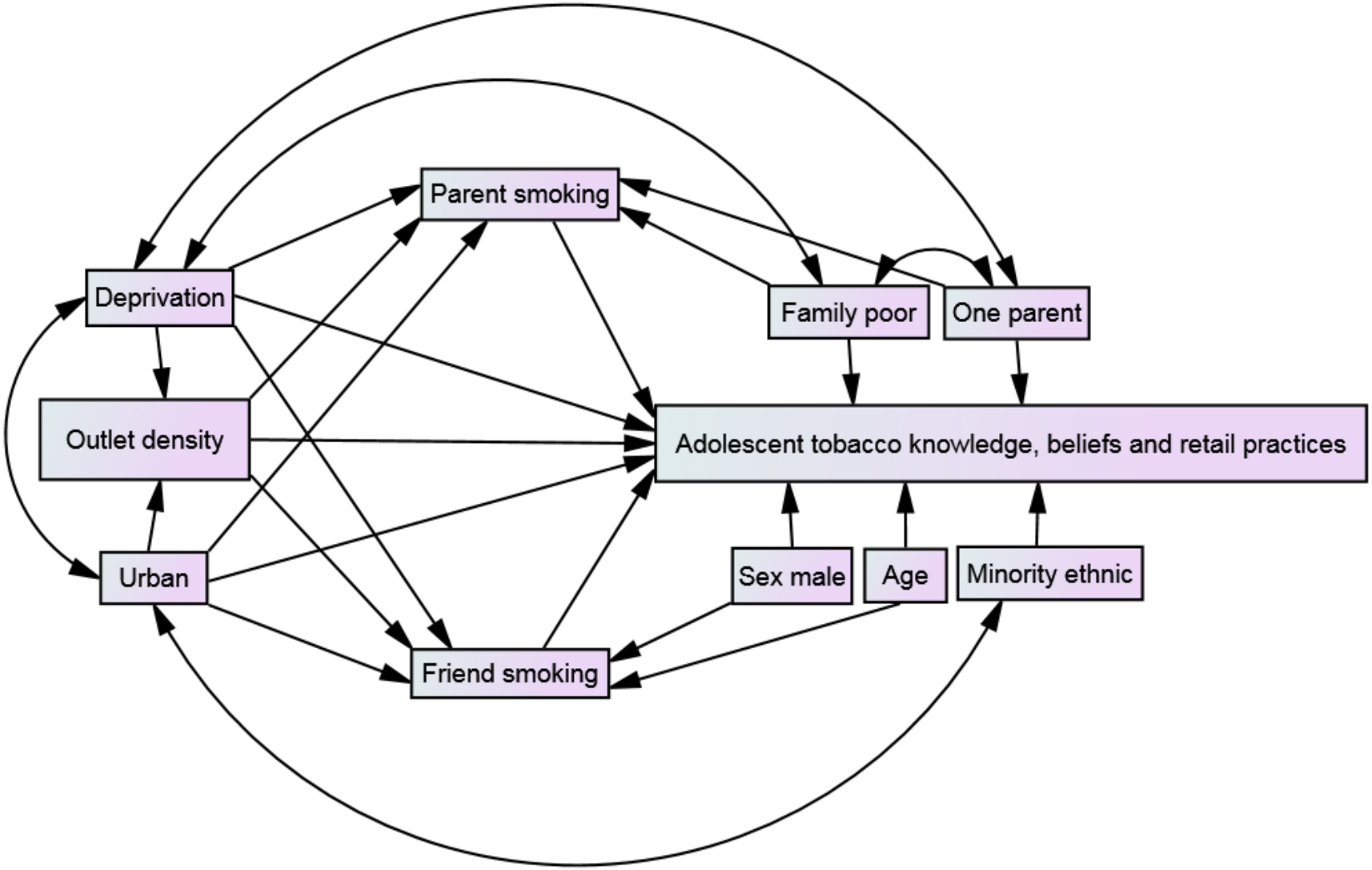
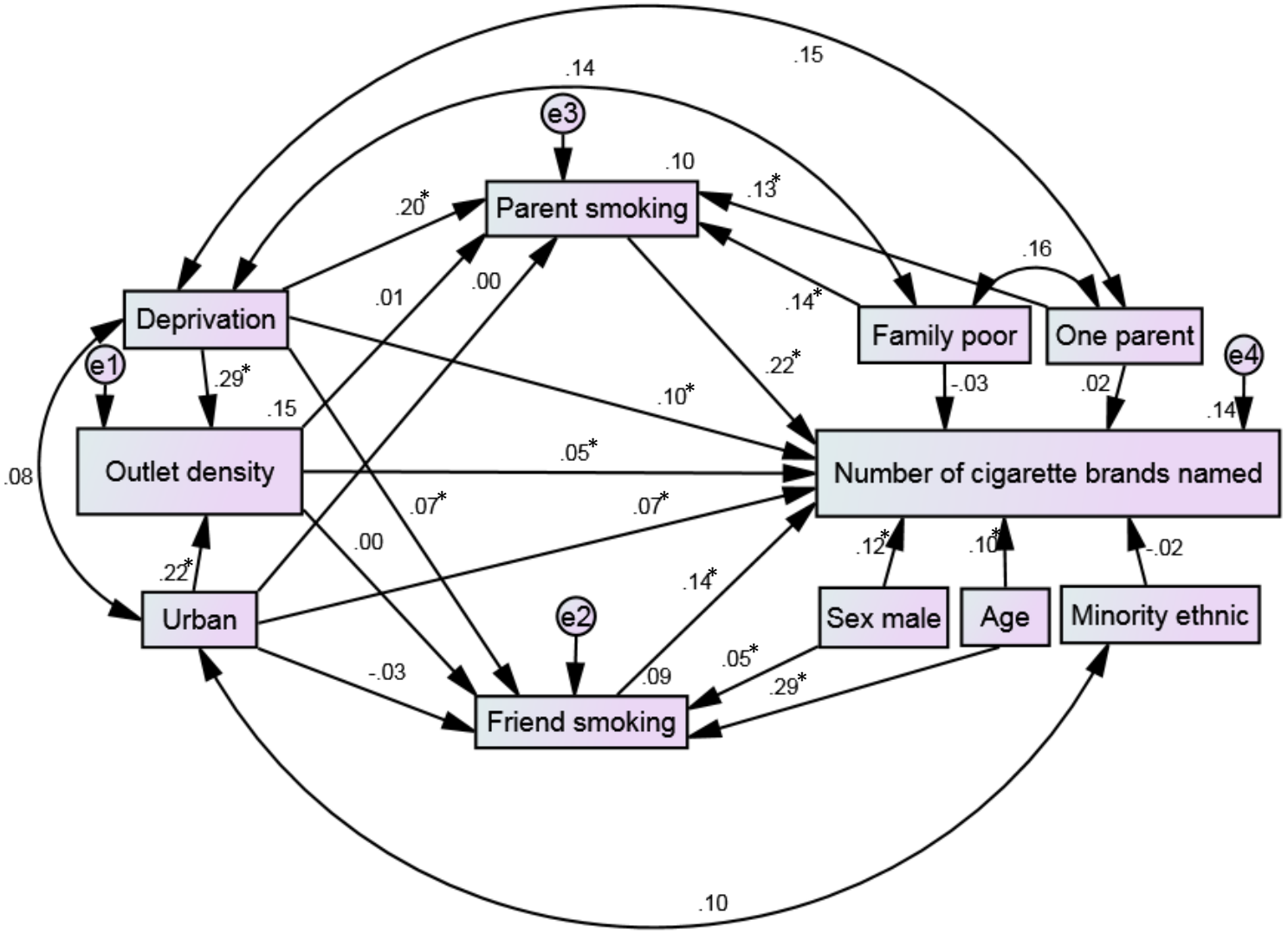

Parent smoking
Deprivation
Family poor
One parent
Outlet density
Adolescent tobacco knowledge, beliefs and retail practices
Urban
Sex male
Age
Minority ethnic
Friend smoking

Figure 3.



*Standardised direct effects significant at 0.05 level

Research highlights

- Tobacco outlet density has been described as a new frontier in tobacco control.
- Pathways linking density of tobacco outlets to smoking behaviour are unclear.
- Adolescents in Scotland in high density areas know more cigarette brand names.
- No association between outlet density and adolescent smoking beliefs.
- Adolescents in high density areas weren't more likely to buy cigarettes in shops.